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Veröffentlicht in:
Multikonferenz Wirtschaftsinformatik 2012
Tagungsband der MKWI 2012
Hrsg.: Dirk Christian Mattfeld; Susanne Robra-Bissantz

MK
WI
'12

Braunschweig: Institut für Wirtschaftsinformatik, 2012

Empirical Support for the Usefulness of Personalized Process Model Views

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Abstract

Business process models are a valued asset to support the communication between a range of business professionals. While it has been common to display process models in the same way as they are created, recent approaches support the use of personalized views on such models. This paper presents one of the first empirical studies that demonstrate the importance of model adjustment to end user preferences. In particular, the results suggest that end users can inspect a process model in accordance with their preferred style of granularity (modular or flattened) without any negative effects on their performance in making sense of such a model. This is a valuable result since it allows for a "separation of concerns", i.e. automatic tools can take over part of the modeler's task with respect to addressing end user needs.

1 Introduction

Organizations in a wide range of domains use models of their business processes to foster a cross-departmental understanding of their business operations. Until recently, business process models would normally be used in exactly the same form as their modelers had created and stored these. With the emergence of collaborative modeling suites and digital repositories of process models, this situation is changing. The display of a business processes model may and, according to some, should be attuned to the individual preferences of a model reader. This has led to the development of approaches that provide personalized views on process models [e.g., 1,22,9]. Despite the notable technical advances, no empirical evidence has been reported on the benefits of personalized visualizations of process models. In other words, it is not known whether a model that is adjusted to the preferences of a particular model reader will be more or less easily readable to her. Arguably, the lack of empirical support for the benefits of personalized process model views forms an obstacle to the further adoption of the supporting techniques. Consequently, process modelers at this point are burdened with contradicting style guidelines and may arguably spend their time on the wrong tasks (e.g. introducing superfluous subprocesses).

In this paper, we tackle this issue by an experimental design. In this design, end users are able to select from a range of semantically equivalent variants the process model that they find most suitable to perform an analysis task. There are indications that the concept of modularity – which allows for different granularity levels of a process model without affecting its meaning – plays a role in the sense-making of very large process models [15]. Because of this insight, we created variants for process models of modest size (in the range of around 25 BPMN process elements). The experiment we designed is developed to address the following questions:

1. Do end users prefer *flattened* process models, i.e. process models where all elements are modeled on the same hierarchical level, over *modular* process models, i.e. process models with subprocesses, to make sense of these?
2. Is an end user's understanding of a process model affected by her preferred model style?

Against this background the remainder of this paper is structured as follows. The following section summarizes related work. Section 3 presents the research design we have developed to confirm our conjectures about the usefulness of personalized process model views. Section 4 summarizes the results of our empirical study. In particular the application of our research results and implications and limitations of this study will be discussed. The paper ends with conclusions and a reflection.

2 Related Work

The creation of different views of a process model depends on user preferences, which may be related to how understandable a particular model actually is for a user. It has been noted that factors such as model aspects (such as structural properties or model size), personal factors, model purpose, problem domain, modeling notation, and visual layout all have an impact on understandability [16]. However, empirical support to a wider extent is missing to confirm this. The influence of model aspects such as model size and model structure has been evaluated by [11], who found out that the overall degree of understandability depends among others on model size. In [2], a family of experiments on a set of 18 process models is described, which shows that a higher number of activities in a process model leads to a higher time that is needed to make sense of it. On the basis of empirical analyses, [12] states that it is advisable to decompose a process model if it has more than 50 elements to reduce the risk on errors and improve its understandability. Given this background, general insights seems to exist on factors that affect the understanding of a process model, but evidence is lacking on user preferences with respect to process model composition and understandability. A personalized visualization of process models is not at all the status quo, despite a plethora of approaches that postulate its importance [1,22,9]. For instance, [1] have already identified that process models should be individually displayed and not in the same way as designed by the modeler and suggested a sound solution for personalization. [17] identified that understandability has a significant effect on the perceived usefulness of a model, in particular that a good understanding of the business process facilitates the identification of requirements on a system that supports such a process. Consequently, understandability may suffer if a process model cannot be adjusted to a modeler's preferences.

To summarize, the empirical insights into personalized business process views that we seek would complement the existing streams of research and potentially increase the value of existing approaches for personalizing the visualization of process models.

3 Research Design

To evaluate the usefulness of personalized process model views, we conducted an empirical study. The motivation to conduct it was formed by several observations we made in past experiments and a theoretical background that we built our research design upon. The seven process modeling guidelines in [12] state that it is advisable to decompose a process model if it has more than 50 elements to reduce the risk on errors and improve its understandability. In a blog response[1] to this publication the advice is given to limit the number of activities on any process level to five or ten for the sake of understandability (cf. [19]). As mentioned in the introduction, the concept of modularity in a process model (through the use of subprocesses) appears to have a positive connection with its understandability. We wondered about end users who may have a preference for a process model style in relation to a process model's size? Our considerations resulted in the formulation of the first hypothesis:

H1: For process models of moderate size, end users do not have a preference for versions with subprocesses over flattened versions.

In this context, the notion of 'moderate size' relates to a process model with less than 50 process model elements.

To broaden and deepen our considerations about the relationship between process model styles and understandability we considered Ockham's Razor principle that says that "when you have two competing theories that make exactly the same predictions, the simpler one is the better" [3]. Simplicity is inverse to complexity and both terms are perspective notions, which means that they depend on the context of application and the user's prior understanding [5]. Referring to business process models' "simplicity" depends on the same factors, i.e. context of application and user's understanding. Consequently, with respect to different model styles (flattened and modular) we have to study its connection with understandability. Therefore our second hypothesis is:

H2: Understandability of a process model of moderate size is not affected by the preferred use of a flattened or a modular process model.

[1] See http://www.brsilver.com/wordpress/2009/12/11/process-modeling-euro-style/

3.1 Empirical Motivation

Over the past years we conducted several empirical studies on business process models, serving different intentions. We gathered within these studies several observations on model size and different process model styles that we wanted to test at some stage. In April 2007, 55 persons with varying modeling experience were asked to fill out a (self-administered) questionnaire. Their task was to select appropriate process model parts that were suitable to complete an editing process model. The process model parts were competitive alternatives, showed different control-flow structures and number of elements. Our observation was that there was no preference for one process model. Instead, modelers selected processes of different model size. Referring to H1 this result would suggest that no preference for a process model's style exist during process re-use. In another empirical study, as conducted in October 2008 [7], 28 graduate and post-graduate students were asked to model a business process on the basis of an informal description of the procedure in use. The participants were given access to a repository of process model parts, and could reuse these model parts to fulfill their modeling task. The model parts varied with respect to the number of model elements (14 to 26). Along with this task, we asked the participants to provide reasons for following up with a model part and the information that they used in this decision making process. Nobody stated as reason for following a process model part the size of the model. The analysis also did not indicate any relationship between process model size and the number of selection of a process model part, nor any relationship between model style (flattened vs. modular) and its selection frequency. Subsequently, we wondered if modelers are indifferent to process model size and process model style.

To provide evidence about these observations and to test the two hypotheses we conducted the empirical study that we will explain next.

3.2 Design Setting

Hypothesis *H1* directly contradicts various practical guidelines that exist, which suggest using subprocesses as soon as process models grow beyond 5-10 process elements. Rather, we contend that a considerable population of end users will prefer to have an aggregated and integrated view of a process model instead of having to browse through different sublevels. Hypothesis *H2* formalizes our conjecture that the task of sense-making of models of moderate size, i.e. below 50 elements, is actually not affected by the use of subprocesses. Our main motivation here is the lack of any significant error rates that are noted in such small models [12].

Objects. The objects evaluated by each participant were either 5 or 6 processes modeled in BPMN. The process models varied in the number of elements and the usage of subprocesses. Four process models were selected from practice, for which we derived variants. All process models from practice were flattened models, i.e. having all elements on one level of abstraction. The selection for a process model depended on (1) the number of elements. We selected process models varying in range of process elements, having at least 10 activities (since [19] gave the advice not to use more than 10 activities, we wanted to investigate implications of larger process models); (2) Control-flow constructs: we selected process models with a similar number of process elements but having different control-flows.

The process model variants were created manually by refining activities. Figure 1 shows on the left hand side two original process models and on the right hand side its variants[2].

Factors and factor level. In our study, the use of subprocesses is the considered factor, with as factor level the number of subprocesses used.

Response variable. The response variable in our study is the level of understanding that the respondents display with respect to the process models, both in their modularized and flattened form.

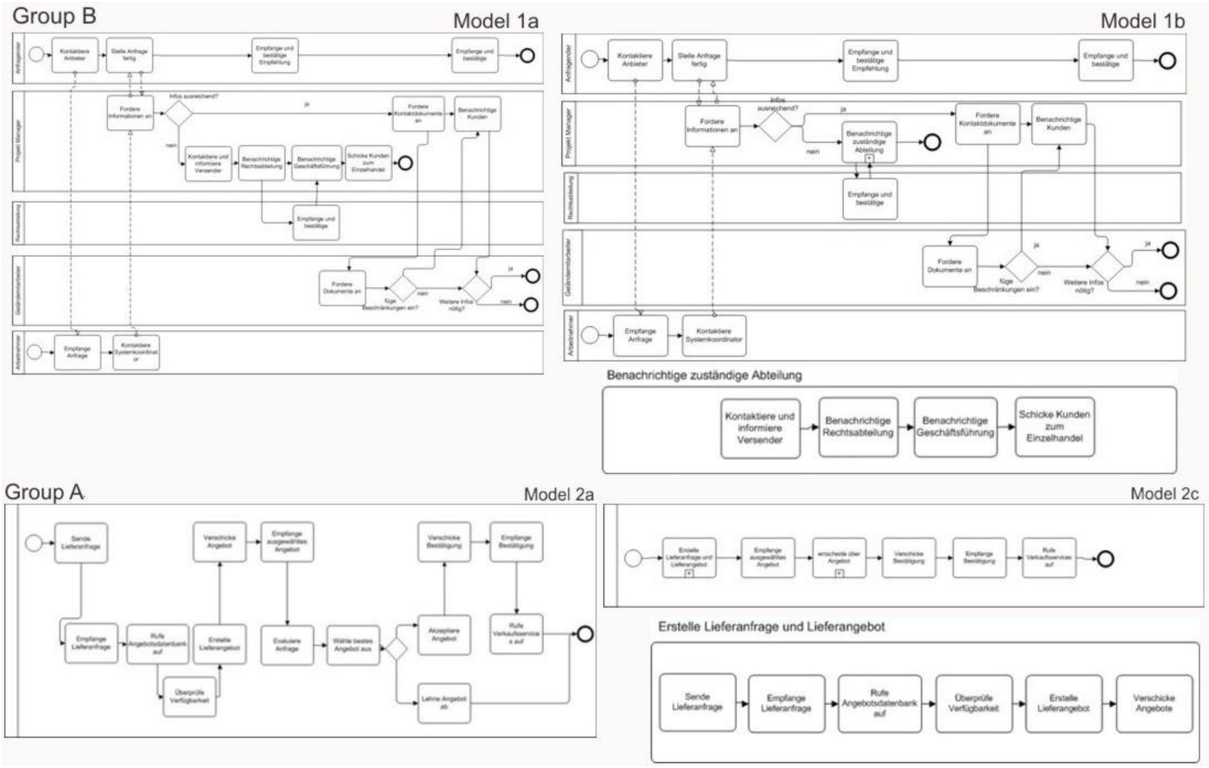

Figure 1: Process Models of the Questionnaire

Subjects. The empirical study that has been conducted took place in the semester of 2010 and involved 39 students. The students either followed a course in Modeling of Business Processes at the Karlsruhe Institute of Technology or in Business Process Modeling at the Cooperative State University Karlsruhe. Three studies [16,6,20] indicate that (advanced) students can serve reasonably well as proxies for process modeling experts. All subjects were educated in BPMN. We provided two types of questionnaires (Group A and Group B) in order to avoid information exchanges between students. We randomly assigned the questionnaires to members. Each member of both groups viewed two flattened process models and the rest were modularized process models. Filling out the questionnaire was voluntary.

Instrumentation. The study was conducted in the following way. The participants received all material on paper. They were asked to carry out a similar selection-understanding task twice. This task demanded a selection of one process model variant from a number of

2 Figure 2c had a second sequential subprocess. Process models from the questionnaire can be downloaded at http://people.aifb.kit.edu/ako/Questionnaire.pdf

available alternatives and then to answer a set of multiple choice questions about this variant. In our context, a process model variant contains one process model or a set of related process models. Among the alternatives was always the variant that only contained the original, flattened process model (i.e. without any subprocess). The other variants contained one main process model, which included one or more subprocesses; the content of the subprocesses were provided in separate models that were part of the variant. Group A received three questions for each of their two selection-understanding tasks and could therefore make 6 mistakes at most. Group B received three questions for their first task and two questions for their second task and could make 5 mistakes at most. For instance, one question was to assess the correctness of the statement that “the process is instantiated with one message-receiving event” (the process had two start events and one message-receiving event where any event instantiates the process). By formulating the questions, we made sure that both global and local questions were used because of its importance in making sense of process models with subprocesses versus those that are fully flattened [15]. In the case of a process model with subprocesses, a local question can be answered by observing a single (sub)process model; a global question cannot be answered in this way. Table 1 shows the process model variants that group A and group B received for each task.

Group A				
Task	Sum Elem.	# Elem. 1. Level	# Elem. 1. Subprocess	# Elem. 2. Subprocess
1a	20	20 (10 activities)	-	-
1b	21	16 (7 activities)	5 (4 activities)	-
2a	17	17 (14 activities)	-	-
2b	17	13 (11 activities)	4 (4 activities)	-
2c	18	8 (6 activities)	6 (6 activities)	4 (4 activities)
Group B				
1a	24	24 (15 activities)	-	-
1b	25	21 (12 activities)	4 (4 activities)	-
2a	20	20 (13 activities)	-	-
2b	23	13 (8 activities)	10 (6 activities)	-
2c	25	15 (8 activities)	10 (6 activities)	-
2d	25	11 (6 activities)	14 (9 activities)	-

Table 1: Number of Elements for Tasks of Group A and B

For both groups, model variant 1a was the original, flat version depicting a real process. Alternative 1b, by contrast, contained one process model that included a single subprocess and a separate model detailing that subprocess. For both groups, model variant 2a once again represented an original, flat model of a real business process. For group A, the distinction between variants 2b and 2c is the number of subprocesses used in the main model, which respectively amounted to 1 and 2. Note that for group B, there are three alternatives to the original process model with the same factor level, i.e. exactly one subprocess. As will be explained in the results section, these similar versions were added to check for the influence of the distribution of activities over the process models belonging to a variant. Altogether, the summed number of process model elements that belong to the same variant ranges between 17 and 25 and the number of BPMN activities between 10 and 15.

Data collection. Within this study we obtained the following data: (1) The selection of the process variant for each task and (2) the number of correct and wrong answers provided by each participant per task.

4 Results

The questionnaire was answered by 39 graduate students. The duration for answering the questionnaire was about 25 minutes. The students did not receive any incentive. We motivated the students to participate as a good preparation for the exam. Table 2 shows the frequency of selected process variants and the average mistake rate. Since the number of questions is not the same for all tasks, the percentage of mistakes against the number of questions is also shown. The first three columns refer to selections of group A and the last three columns to selections of group B. Note that three members did not answer question 2. The number of subprocesses and elements per process model can be found in Table 1.

Group A			Group B		
Task	Freq. Selection	Avg. Mistakes	Task	Freq. Selection	Avg. Mistakes
1a	12	0.667 (22%)	1a	14	1.000 (33%)
1b	5	0.400 (13%)	1b	8	0.875 (29%)
2a	9	0.667 (22%)	2a	8	1.000 (50%)
2b	1	0.000 (0%)	2b	4	0.500 (25%)
2c	6	0.333 (11%)	2c	2	1.000 (50%)
			2d	6	0.500 (25%)

Table 2: Frequency of Selection and Average Number of Mistakes.

If we consider the preferences of groups A and B for the process model variants they wish to use for answering the model questions, the following is visible. For the first task, both groups seem to prefer the flattened, integral model (1a) over the variant that contains a process model with one subprocess (1b). Approximately, the ratio of people selecting variant 1a versus 1b is 2:1, which seems to strongly support H1. In other words, modular models are not at all preferred. Furthermore, no strong preference for modular process models is apparent for the second task. Here, the participants of group A actually display a U-shaped distribution of preferences, with 9 participants (56%) selecting the flattened model (2a) and 6 of them (38%) the process model with two subprocesses (2c). If we consider group B, it should first be recalled that variants 2b, 2c, and 2d all contain one subprocess. Then, 8 participants of this group (40%) prefer the flattened, integral model (2a) and 12 participants (60%) a variant with one subprocess (2b, 2c, and 2d). When considering all results for the selection part of the task, a slight preference for flattened models seem to exist: Of the 75 decisions in total, the flattened version was selected 43 times and a process model with at least one subprocess was selected 32 times. In our view, these results do not support the view that process models with subprocesses are preferred. Hence we accept H1: For process models of moderate size, end users do not have a preference for versions with subprocesses over flattened versions.

To investigate H2, we analyzed the rates of mistakes between the participants that used different variants for each task. Since the distribution of the number of mistakes is not normally distributed, we applied the non-parametric Mann-Whitney (in the case of two variants) and Kruskal-Wallis tests (in case of more variants) to detect any significant difference in the performance of participants using different models [18]. The resulting p-values are shown in Table 3. Since all the p-values well exceed the threshold of 0.05 (using a confidence level of 95%) no significant differences can be observed. Note that for the second selection understanding task of each group, we both checked for performance differences across all available variants (e.g. for group A between variants 2a, 2b, and 2c) and for differences between using a flattened or non-flattened process model, which disregards the actual number of subprocesses (e.g. for group A between variant 2a on the one hand and variants 2b and 2c combined on the other). Finally, we also checked for the second modeling selection-understanding task of group B whether differences could be detected between variants 2b, 2c and 2d. The variants have the same factor level (one subprocess) but a different distribution of activities over the models. Given the p-value of 0.446, this does not indicate a different performance between the groups.

Group A	Task	p-value	Group B	Task	p-value
	1a vs. 1b 2a vs. 2b vs. 2c 2a vs. (2b + 2c)	0.677 0.446 0.278		1a vs. 1b 2a vs. 2b vs. 2c vs. 2d 2a vs. (2b + 2c + 2d) 2b vs. 2c vs. 2d	0.738 0.406 0.201 0.446

Table 3: P-values for Tasks of Group A and Group B

Overall, the results for the sense-making part of the task give some reassurance that the actual distribution of the activities over the levels does not play a significant role. Given these results, we feel confident to accept H2: Understandability of a process model of moderate size is not affected by the preferred use of a flattened or a modular process model.

5 Discussion

In this section, we put the results of our study in a wider perspective. First of all, we will discuss the implications for research and practice, after which we will describe the limitations of our research.

5.1 Implications

Our results suggest that modelers during the creation of process models can be relieved from some concerns. In particular, the decision for the best level of granularity that can be used to understand a process model can be shifted to end users. This insight has implications for two streams of research: (1) process model size and (2) personalized process views.

Process model size. An inappropriate threshold for model size is counterproductive. A threshold that is too low will burden process modelers with unnecessary efforts to decompose process models, while a threshold that is too high potentially leads to models which are hard to understand. Also, it is noteworthy that size has not been shown to be related to the quality of other types of conceptual models. In [15], a study is reported where no evidence is found that the size of a diagram in terms of number of entities (of an ER diagram) affects understandability. As a result, uncertainty has continued to exist about, for example, the appropriate use of subprocesses in process models and a proper threshold for model size. Our study results resolve this issue for process models of moderate size by turning away the attention of process model granularity at design time and moving it to the personal preferences of end users.

Personalized process views. The empirical results reported in this paper are in line with approaches for personalized visualization on models [1,22,9]. These approaches assume that personalized views are essential, but no empirical evidence exists for this. Our study supports the usefulness of personalized visualization options and encourages their wider study. In particular, since we have only considered options to influence the granularity, it may be of interest to investigate further options for personalization:

- *Process element labeling.* Process elements can be labeled using verb-object or action-noun styles. The activity labeling can be (semi-)automatically detected [14] and transformed into the preferred labeling style.
- *Colors of process elements.* Usually, the colors of process elements are predetermined (e.g., green and purple tones for EPCs). The preferences for colors may vary per user. For instance, some users want to highlight the output of a process model in red. The preference for a style can be determined using pattern recognition.
- *Usage of icons instead of graphical elements.* The activity of a process model can be replaced or extended with a pictogram (e.g., a person working with a computer denotes the activity "enter data into database"). The preference of users can be detected using machine-learning techniques.
- *Alignment of elements.* The alignment is predefined for process modeling languages. E.g., EPCs are modeled top-to-bottom, while the BPMN specification recommends modeling either left-to-right or top-to-bottom. One can imagine user preferences for more hybrid lay-outing of the process models.

5.2 Application of research results for process modularization

The results show that the use of modularization in this case does not help to improve understandability. However, provided it is done right, modularization should help to reduce the complexity of process models (and thus improve understandability) in the following three ways. Modular process models of modest size should have:

1. a lower number of process elements per (sub)process;
2. a high interconnectedness between elements from the same (sub)process; and
3. a low interconnectedness between elements from different (sub)processes.

These properties help to reduce complexity and improve understandability as follows. Having a lower number of process elements per (sub)process, helps to maintain an overview. Having a high interconnectedness between elements from the same process, while having a low interconnectedness between elements from different processes, helps to keep each (sub)process self-contained. Therewith it is understandable as a single unit. The latter two criteria are also frequently used in modularizing software design, often in relation to the notions of cohesion and coupling. There exist metrics to determine the extent to which these criteria are met with the modularization of a process [15]. Table 4 shows these metrics as they are applied to the process models from the experimental setup. The connectivity (Conn) is the number of arcs divided by the number of process model elements. A decrease in this number means that there are less interconnections between process models elements, thus leading to a more understandable model. The density (Dens) is the number of arcs in a subprocess divided by the (hypothetical) maximum number of arcs, which is $n \cdot (n-1)/2$, where n is the number of elements in the subprocess. An increase in density means that there is a relative increase in the interconnectedness between elements from the same (sub)process. The average connection degree (Conndeg) is the average number of input or output arcs per process model element. Similar to the connectivity, a decrease in this number means that there are less interconnections.

Group A				Group B			
Process	Conn	Dens	Conndeg	Process	Conn	Dens	Conndeg
1a	1.15	0.12	1.13	1a	1.17 1.04	0.10 0.12	1.15
1b	1.10	0.18	1.07	1b			1.06
2a	1.00	0.13	1.00	2a	1.10 1.04	0.12 0.20	1.08
2b	0.88	0.18	0.88	2b	1.20 1.12	0.20 0.28	1.02
2c	0.83	0.31	0.83	2c			1.18
				2d			1.10

Table 4: Complexity of the (modularized) process models

The table shows that for the modularized process models, both the connectivity and the average connection degree decrease, while the density increases. Only for the processes 2c and 2d in group B, there is a slight increase in the connectivity and average connection degree. Table 1 shows that the number of process model elements per process also decreases for the modularized process models. This provides evidence that the modularization indeed reduces the complexity of the process models according to the three criteria presented above. Interestingly, although these results show a decrease in complexity, the understandability of the models does not improve significantly. This further supports our hypothesis that personal preference is a (more) important factor for understandability than modularization. An alternative explanation for this phenomenon, however, is that the criteria that are commonly used for good modularization, as they are explained above, are not adequate. In other words: there is a possibility that our models are not modularized in the right way and that the modularization of the models does not improve understandability for that reason. This alternative explanation is also supported by an earlier study [15], in which we did not find a clear relationship between modularization and understandability.

5.3 Limitations

Only a number of 39 participants were involved in this study. The involvement of students always raises discussions about the external validity of the results. Clearly, the usage of students instead of practitioners has advantages because it allows to easier control human factors (e.g., training, technical modeling skills) that impact user attributes [10,21]. Several experiments have investigated the similarities and differences of responses between industry people and students [6,20] and justified the usage of students for empirical studies instead of professional workers. Our considerations are based upon results that were obtained from empirical studies where participants had varying levels of modeling experience (see Section 3.2).

6 Conclusion

On the basis of an empirical study that is presented in this paper, a main result is that modelers do not seem to have a preference for a process model with subprocesses over flattened process models. This result should be interpreted in a setting where the model comprises some 20 process elements. This finding contradicts various practical guidelines that already prescribe the use of subprocesses for smaller process models. An implication of this result is that process modelers should not feel burdened to apply subprocesses on process model levels that contain a range of 20 elements. Another main result is that the level of understanding that different end-users can distill from a process model is similar when it is displayed in accordance with their preferred visualization style. In other words, a preference for a process model with or without subprocesses does not affect one's understanding. The finding makes a strong case for the use of personalized model views and the uptake of available approaches in this field. In the reported follow-up analysis, we noted a decrease of complexity of the process models due to the use of subprocess but without a notable effect on their understandability. This further supports our hypothesis that personal preference is a (more) important factor for understandability than modularization. With respect to the subject of sense-making of process models, we see that a range of research opportunities still exist. The impact of personal characteristics on the one hand and the secondary notation of a process model on the other (e.g. process model lay-out) are notable factors that require further investigation. For the future, we would be happy to see works aiming to resolve contradictory modeling guidance and to transfer insights from BPM research to practice. Considering empirical business process research, the results presented in this paper can further contribute to the understanding of the act of business process modeling. For modelers these results are valuable and generally leave room for attuning their models to end user needs without influencing their resulting comprehension efforts. Besides personalized visualization of process models, our empirical findings can be further exploited. In the context of business process model abstraction [13] firmer insights into the impact of modeling style should offer different types of abstraction (depending on users' preferences) and a less restrictive abstraction of process elements (e.g., also an abstraction with up to 25 elements does in the end not affect understandability). Finally, in the context of process modeling support tools (e.g., tools suggesting process model parts that are suitable to complete a model [8]), one can imagine the recommendation based upon personalized process model views. A recommended process model can be displayed with respect to a user's preferences.

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